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ABSTRACT

This paper examines theories on metacognition and instructional strategies for developing metacognitive processes. These strategies were then implemented in an inner-city grade 6 classroom in a low-economic, multicultural section of Vancouver, British Columbia (Canada), in which 33 students kept journals that were studied for evidence of metacognitive development. Journal entries formed the basis for responses to six research questions. Conclusions include the following: (1) children at age 11 have varying metacognitive abilities; (2) metacognitive processing is an attribute most children could access but for various reasons could not do so effectively--children who were easily distracted, passive, or had low self-esteem appeared to accept that they could do little about their achievement; (3) problem-solving performance improved within, but was not necessarily attributable to, small group work; (4) children lacking both interest in school and ability to concentrate on their school work do not appear to access metacognitive processes for academic work; (5) teachers need to set clear expectations and teach social skills to provide the type of social interaction that fosters metacognitive development; and (6) theories of metacognition can be integrated into existing teaching strategies. (51 references) (MDH)

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IMPLEMENTING METACOGNITIVE PROCESSING IN THE MATHEMATICS CLASSROOM

By

Margaret Eileen Williamson

B. ED., The University of British Columbia, 1969

A MAJOR ESSAY SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
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We accept this Major Essay as conforming
to the required standard

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THE UNIVERSITY OF BRITISH COLUMBIA
AUGUST 1991

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Chapter 1: Introduction

The purpose of this paper is to examine theories on metacognition and demonstrate how the theories were implemented by a grade six mathematics teacher. Changes in the classroom organization involved implementing elements of metacognition within existing teaching strategies as a means to improve students' mathematics performance. It was believed that by facilitating the development of metacognitive processes in children, the children would be made aware that they could modify their attitude towards learning and their level of attention in a mathematics classroom, and it was expected that they would become better learners.

Upon perusal of the literature on metacognition and its link with problem solving, hypotheses about how the classroom teacher might foster the development of metacognition in problem solving raised a series of questions for this author which required answers:

1. Can children of age eleven be taught metacognitive processing?
2. Which children are aware of their own metacognition?
3. Does involvement in cooperative problem solving with a focus on metacognitive processing improve childrens' problem solving performance?
4. Is there a link between children's attitudes towards school learning and their awareness of their metacognitive processes?
5. How can a teacher provide the type of social interaction between students and between student and teacher to facilitate the development of metacognition?

6. Can theories on metacognition be integrated with existing teaching strategies?

In Chapter Two, the author presents and clarifies the theoretical positions about metacognitive processes and identifies perspectives that influenced changes in her classroom organization, lesson formats, and student activities during the 1990-91 school year. The literature review will:

* clarify three aspects of metacognition (reflective access, self-regulation, and executive control) and the concept of other-regulation that play an important role in activating student learning;
* present the instructional strategies recommended by education researchers for the development of metacognitive processes;
* describe the role that social interaction is thought to play in the development of metacognition in children; and
* review what is known about student interaction in small group work, also known as cooperative learning.

In Chapter Three, the author presents a profile of her grade six class, the context of the mathematics program, and the way the classroom activities and routines were developed.

In Chapter Four, the author investigates how the theories functioned in practice and summarizes the understandings gained and adjustments made to instructional strategies throughout the year. Reconstruction of documented classroom events focusing on the social

dynamics, classroom constraints, and learner characteristics provides the basis for an evaluation of the implementation of the current theories of metacognition in a grade six classroom. The pupils' perspective is provided through their written comments on specific mathematics lessons and their reflections on their progress in and attitude towards learning mathematics.

Chapter 2: Theoretical Orientation

Metacognition

There is considerable confusion in the literature about what is and what is not metacognition. This confusion has led to contradictory viewpoints that range from claims that "the concept is too ill-defined or fuzzy to be the object of scientific inquiry to assertions that things metacognitive are the driving force of learning, and therefore the major aspect of learning we should be studying" (Campione, Brown, & Connell, 1988, p.93). Flavell (1976) who brought prominence to metacognition through his laboratory research on metamemory provided the following frequently quoted definition for the term metacognition:

> Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them...For example, I am engaging in metacognition... if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as a fact...Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes...usually in the services of some concrete goal or objective.(p.232)

Thus, Flavell focuses on two aspects of metacognition. The first aspect is the knowledge that one has of being a conscious, deliberately acting thinker and the second is the control that one brings for monitoring cognitive strategies.

In contrast, Marzano et al. (1988, p.9-16) separate the concepts of knowledge and control into knowledge and control of self and knowledge and control of process. From the

first concept, knowledge and control of self, comes the suggestion that learners are capable of self-regulation. Marzano et al. present three aspects of self-regulation: monitoring and controlling commitment, monitoring and controlling attitudes, and monitoring and controlling attention. Good learners monitor and control their own level of commitment, attitude, and attention. From this concept of metacognition comes an assumption that all students can be made aware of general metacognitive strategies that can provide them with the power to generate commitment and take control of their attitudes and influence their levels of attention.

Within the second concept, knowledge and control of process, there are two important elements: the types of knowledge important in metacognition and the executive control of behaviour. To exert metacognitive control over a "process", students must know what facts and concepts are necessary for the task (declarative knowledge); which strategies, heuristics, or procedures are appropriate (conditional knowledge); and how to apply the selected strategy, procedure, or heuristics (procedural knowledge). Executive control of behaviour requires the ability to consciously plan, monitor, evaluate, and revise one's progress in a learning situation.

Schoenfeld (1987b, p.189-190), a mathematics educator and researcher, takes yet another approach and summarizes the concepts of metacognition in the following related but distinct categories of intellectual behaviour:

1. Your knowledge about your thought processes. How accurate are you in describing your thinking?

2. Control, or self-regulation. How well do you keep track of what you are doing when (for example) you are solving problems, and how well (if at all) do you use the input from those problem solving actions?
3. Beliefs and intuitions. What ideas about mathematics do you bring to your work in mathematics, and how does that shape the way that you do mathematics?

In summary, metacognition refers to the knowledge and control one has of one's cognitive processes. Metacognition is thinking about thinking and managing thinking.

Importance of Metacognition

Many of the individuals considered successful in today's technological society are aware of their cognitive processes and exert conscious control over them. Peters and Waterman (1982) cite numerous examples of top executives cultivating such metacognitive strategies as goal setting, monitoring feedback, and cognitive restructuring. The educational community that is involved in curriculum development has highlighted the importance of these strategies for some years and suggested that metacognitive awareness be a part of the education process. Society is now wanting educators to maximize student learning and assist students in becoming independent learners. At present few components of metacognitive processing are systematically taught in mainstream education. Outside of the mathematics education community, the teaching of metacognitive processes is often labelled "learning to

learn" (Marzano & Arredondo, 1986). Mathematics educators' interest in the role of metacognition is focused on improving the performance of mathematical tasks. It is their belief that what one knows or believes about oneself as a learner and doer of mathematics and how one controls and regulates one's behaviours while working through mathematical tasks can have powerful effects on one's performance.

Mathematics education researchers (Anthony, 1978; Lester, 1983; Lester & Garofalo, 1985; Schoenfeld, 1985) who have examined problem solving processes, heuristics, and strategies as ways to improve problem solving performance have found that the failure of such efforts was largely due to the fact that instruction had overemphasized the development of heuristic skills and ignored the managerial skills necessary to think about what one is doing. While studying how to help students take charge of their own learning, Lester (1988, p.117) wrote, "I became convinced that training in the use of a collection of skills and heuristics without attention to affective and metacognitive aspects of problem solving is inadequate."

Several researchers (Slife, Weiss, & Bell, 1985; Brown, 1987; Narode, 1987) have found that students who fail to do well in problem solving and reading comprehension are deficient in metacognitive processing. These students fail to enlist efficient strategies and regulate their use. Research by Slife, Weiss, and Bell (1985) demonstrated that knowing how to solve a problem was a different skill or ability from knowing that one knows how to solve a problem. In trying to identify the metacognitive differences between a group of students

identified as learning disabled and a group of regular ability peers on a mathematical problem solving task, they were able to show that metacognitive processes are a separate set of skills. Schewel and Waddell (1986) found that metacognitive activity was a critical skill lacking in the learning disabled.

In the opinion of Campione, Brown, and Connell (1988), "Successful learners can reflect, ... have powerful strategies for dealing with novel problems, and oversee and regulate those strategies efficiently and effectively. They find learning challenging and see themselves as in control of their destiny. Weaker students, in contrast, acquire fewer problem-solving strategies, are less aware of the utility of those strategies, and do not use them flexibly in the service of new learning. They are not convinced that they can control their performance and tend to be relatively passive in learning situations" (p.94). Marzano and Arredondo (1986) suggest that the impact of the "learning to learn" skills (metacognitive processes) should be the strongest on poorer students, as they have a deficiency in these processes.

The Nature and Development of Metacognition in Children

According to the literature, there are three theoretical components of metacognition: reflective access, self-regulation, and executive control (Brown, 1987, p.69-105). A definition for each of these terms is provided; followed by theories describing the development of these aspects of metacognition in children. A fourth term, other-regulation, which is seen as a process by which metacognition develops, is also presented.

Reflective access

Reflective access refers to the human ability to step back and consider one's own cognitive operations as objects of thought. In other words, it is the ability to reflect on one's own thinking. Reflective access in combination with self-regulation is an important metacognitive process that enables learners to regulate knowledge and to control self.

Researchers have found that children who know perfectly well how to use a strategy or have the relevant prior knowledge, often fail to access it on appropriate occasions (Costa, 1984; Schoenfeld, 1985; Campione et al., 1988). Reflective access appears to be more difficult for the young pre-school child and the learning disabled child than for children around age twelve (Brown, 1987). One of the primary problems with young learners is that they tend to acquire information that is 'welded' to the form and context in which it was acquired, and many do not transfer the knowledge to similar situations. Brown (1987) suggests that practised learners know certain stable characteristics about themselves as learners; they know the demands of certain classes of problems; and they are aware of the necessity of tailoring their learning activities to meet with specific criterial tasks. Perhaps young children, lacking the repetitive experience of formal learning situations in school, are less aware about how they learn and have yet to develop the ability to verbalize their thinking process to themselves or others.

Knowledge about how and when the ability to access one's reflective thought develops remains fuzzy but the ability does appear to develop with maturity. According to Costa (1984)

and Pressley and Harris (1990), 'self-talk' that is associated with metacognition appears around the age five and is fully developed around age twelve.

Self-regulation

Self-regulation refers to one's conceptual reorganization ability. Much of the theory on self-regulation comes from recent Piagetian research on self-regulatory mechanisms in children's thinking and from the growing emphasis in developmental psycholinguistics on error correction, systemization, and metalinguistic awareness. Piaget has described three types of self-regulation: autonomous regulation, active regulation, and conscious regulation. Autonomous regulation and active regulation are described as follows:

> To encapsulate Piaget's developmental progression: the initial stage of autonomous regulation involves unconscious adjustments and fine tuning of motor actions; next the child becomes capable of testing out theories-in-action, via concrete trial and error. Despite the lack of conscious surveillance on the part of the learner, this active regulation can lead to successful problem-solving. Even though the learner cannot describe how they were accomplished, actions can be successfully completed (Brown, 1987, p.90).

The level of conscious regulation, the ability to step back and consider one's own thought as an object of thought and use the subsequent conceptualization to consciously invent, test, modify, and generalize theories and discuss these operations with others, coincides with Piaget's stage of formal operations (from 11 to 12 years). Brown summarizes Piaget's developmental progression of consciousness:

> Thus, Piaget distinguishes between active regulation as part of any knowing act and conscious regulation and direction of thought. The first process is age <u>independent</u>; even the young learner succeeds in action by regulating, correcting, and refining his or her current theories. The second process, <u>guided</u> by reflected abstraction, is late developing, and indeed, for Piaget, this is the

keystone of formal operational thought (Brown, 1987, p.96).

The metacognitive components of self-regulation and reflective access are necessary for metacognitive activity and develop over the same period of time as does Piaget's stage of formal operations - during the child's elementary school years. To what extent educators can enhance the development of these processes has not yet been determined.

Executive Control

Executive control is the ability to deliberately plan and control one's thinking strategies. The term, executive control, comes from research on information-processing, and is a computer metaphor that has recently dominated theories of human cognition. Executive control is based on the notion of a central processor that contains a hierarchical cognitive system for processing incoming information. Two types of processing which occur are automatic processing and controlled processing. Automatic processing is a fast process which includes those activities that appear to be common to all age groups and rarely demand intensive strategic effort. For example, when children initially learn a new skill such as tying shoe laces they proceed slowly in a controlled manner, step by step. Once the skill has been mastered, tying shoe laces becomes an automatic activity. Only for those children who are learning disabled could this activity not become automatic. A major notion is that a great deal of development that occurs with increasing expertise is the result of processes originally consciously controlled becoming automated through extensive training and experience. Controlled processing is a comparatively slow process, limited by short-term memory constraints, requiring subject effort, and providing a large degree of subject control.

The research literature describes adults who are good planners as making many metaplans and executive decisions and exercising deliberate control over their planning processes (Brown, 1987, p. 86). There is little research (Wertsch et al., 1980) concerned with children's planning behaviour or the influence of task difficulty and familiarity on children's propensity to plan and monitor. Developmental research has yet to support the central place of executive functions, such as planning and monitoring, in human information processing. Some work on comparing novices and experts (Dreyfus & Dreyfus, 1986, pp. 19-37) and on comprehension-monitoring (Garner, 1988) has provided some support for the belief that executive control is an ability that is present in upper elementary and secondary school students and that with instruction most students could improve their access to this planning and monitoring skill.

Other-regulation

Other-regulation is a process by which metacognition develops, rather than an aspect of metacognitive functioning such as self-regulation, reflective access, and executive control. It is a form of mediated instruction that occurs between the learner and a more knowledgeable peer or adult. The mediator guides the learner through an activity by organizing, directing, and controlling the learner's cognitive behaviour. The learner gradually internalizes the structures and regulatory activities being provided. Other-regulation appears to precede self-regulation and the concept is founded in Vygotsky's (1978) theory of internalization. Vygotsky sees social interaction playing a fundamental role in shaping internal cognitive structures:

> Every function in the child's cultural development appears twice: first on the social level, between people... and then inside the child. This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All higher functions originate as actual relationships between human individuals. (p.141)

Vygotsky proposes that an essential feature of learning is that it creates a zone of proximal development. This refers to a learning potential that may be actualized under the direction of adult or peer guidance. What a child can do with the assistance of others might in some sense be more indicative of his or her mental development, rather than what he or she can do alone. In other words a child's actual developmental level defines functions that have already matured and the zone of proximal development defines those functions that have not yet developed but are in the process of developing.

The behaviour of self-regulation (the ability to direct and control one's own cognitive behaviour) reflects the gradual internalization of the processes which adults and more knowledgeable others have previously provided, organized and directed (Vygotsky, 1978). Wertsch, McNamee, Mclane, & Budwig (1980) illustrated the developmental progression from other-regulation to self-regulation in successful mother-child learning situations. The mothers communicated differently with children at different ages. With younger children the mothers took on the responsibility for making certain that information from the model was used appropriately whereas with the older children, appropriate use of the information was made without adult guidance. Their learning to learn process involved a mediator (the mother) who took on the role of promoter of self-regulation by nurturing the emergence of personal

planning and who gradually lessened her direction as the child began to plan and monitor his or her own activities. This mediation provided a scaffold for entry into the child's next level of learning.

A deficiency of other-regulation has been indicated as a primary source of developmental retardation (Feuerstein, 1979; Brown, 1987). Feuerstein's learning theory holds that cognitive growth is very heavily dependent on the quality of mediated learning that a child experiences. According to Feuerstein these mediated experiences are an essential aspect of development, beginning when the parent selects significant objects for the infant to focus on and proceeding throughout development. By interacting with an adult or peer who guides problem solving activities and structures learning environments, the child gradually comes to adopt structuring and regulatory activities for himself or herself. Vygotsky (1978) and Feuerstein (1979) argue forcefully that metacognition is developed through the experiences of social interaction that provide mediated learning.

Instructional Strategies for Developing Metacognitive Processes

> To make an individual that is metacognitively aware, is to ensure that the individual has learned how to learn. The individual behaves in reflective, planful, and where necessary, self-corrective ways. An important feature of executive routines is that they can be taught (Garner, 1988).

Traditionally, mathematics teachers have presented polished solutions to students and hid the strategic decisions and actions that they use in planning, monitoring, and evaluating

their solution processes (Schoenfeld, 1987b, Lester, 1988). Researchers now recommend that teachers provide metacognitive training and focus more on the mathematical behaviour of monitoring, planning, and assessing what is being learned or solved, and emphasize why a strategy should be employed (Schoenfeld, 1985a; Silver, 1985; Garofalo and Lester, 1987; Campione, Brown and Connell, 1988). Available research does not give definite statements about how to teach cognitive and metacognitive strategies but some guidelines can be stated.

Guideline 1: Teach metacognitive strategies in conjunction with content.

Schoenfeld (1987a, p. 17) wrote, "Study after study in mathematics education literature produced 'promising' results where teacher and student alike were happy with the instruction, but where there was little evidence, if any at all, of improving problem solving performance." Since the teaching of problem solving strategies such as draw a picture, make a list, and look for a pattern was not sufficient to enable students to use them effectively, recommendations for more focus on the meta-level processes of planning, monitoring, and evaluating were made.

Although intuitively appealing, there is little in the way of systematic evidence documenting metacognitive growth as an accompaniment to strategy execution. However, Pressley, Borkowski, and O'Sullivan (1985) did find that changes in metamemory did occur through practice of a strategy. Lester, (1988) following his research study with grade seven students, confirmed that control processes and awareness of cognitive processes develop

concurrently with the development of an understanding of mathematical concepts.

The belief that the development of metacognitive processes can be fostered by providing experiences that allow the student to internalize subject knowledge and metacognitive knowledge is only partly supported by Vygotsky (1978). His theory is that developmental processes do not coincide with learning processes, but lag behind.

> Rather the developmental process lags behind the learning process; this sequence then results in zones of proximal development. Our analysis alters the traditional view that at the moment a child ... masters an operation such as addition ... her developmental processes are basically completed. In fact, they have only just begun at that moment. The major consequence of analyzing the educational process in this manner is to show that the initial mastery of, for example, the four arithmetic operations provides the bases for the subsequent development of a variety of highly complex internal processes in children's thinking. (Vygotsky, 1978, p. 90)

In other words, a child can master mathematical content such as the arithmetic operations of addition, subtraction, multiplication, and division, but be unable to use metacognitive knowledge to improve performance in the application of these operations because the metacognitive processes have not yet developed within the child.

Guideline 2: Teach students how to take charge of their own learning.

Marzano and Arredondo (1986), Schoenfeld, (1987b), and Lester (1988) describe roles that the classroom teacher must undertake in order to teach students how to take charge of their own learning: teacher as planner and manager, teacher as a model, and teacher as a mediator.

Teacher as planner and manager

As discussed earlier, development of metacognitive processes is influenced by learning, but learning is also influenced by development of metacognitive processes. Differences between students' academic performances can be related to differences in prior knowledge that they bring to the classroom and in the repertoire of cognitive and metacognitive strategies that they know and use. Teaching students how to use learning strategies will not be enough if the metacognitive processes have not developed. (Metacognitive activity appears lacking in learning disabled students and academically weak children.) Therefore the teacher must plan and provide diverse opportunities for acquiring, practising, and applying learning strategies in order to facilitate the development of metacognitive processes.

When planning for instruction, the teacher must first establish what content is to be learned. For example, the content might be the problem solving strategy - look for a pattern. The organizer for strategy instruction may be Polya's (1945) four step problem solving model: 1. Understand the problem 2. Devise a plan 3. Carry out the plan 4. Look back and check for errors. Then, the teacher needs to consider the following four steps (Marzano et al., 1986, p. 20-26) when organizing for strategy instruction:

1. Provide explicit instruction in how to apply the organizer to a variety of situations.
2. Provide opportunities for the class to work as a whole or in small groups with emphasis on cooperative learning.

3. Provide opportunities for transfer of learning.

4. Provide concerted effort to link the new information to prior knowledge.

Garofalo and Lester (1985) have modified Polya's model to emphasize the coordination of metacognitive and cognitive strategies before problem solving (orienting processes), during problem solving (organization and execution processes) and after it (verification processes). Costa (1984) also suggests that students think of tasks as having before, during, and after components with evaluating, planning, regulating, and revising taking place at each stage.

Costa (1984, p.57-62) provides teachers with specific suggestions for classroom use. Before beginning the solution to a problem, the teacher needs to give students explicit guidelines as this gives them a way to evaluate their performance afterwards. The teacher would point out strategies and steps for attacking problems, rules to remember, directions to follow, time constraints, ground rules for working, and the purpose for planning.

During the activity, the teacher needs to invite students to share their progress, their thought processes, and their perceptions of their own behaviour. This can be done through written comments or dialogue between student and teacher or student and student.

After a solution has been reached, the teacher needs to invite students to discuss the effectiveness of the strategies and the model for problem solving that they are practising, pose

questions that focus on their choices and help the students explore the consequences of their actions and decisions. This may help them perceive causal relationships among their decisions, their actions, and the results they achieved. Questions such as: "What did you do that was helpful? What did you do that was not helpful? What did you do well? What did you like and what did you not like in this activity?" help students evaluate their success or lack of success.

Costa suggests that phrases such as "I can't; I don't know how; and I'm too slow" be outlawed in the classroom. Instead the students must identify what information is required, what materials are needed, and what skills are lacking. This helps students to identify what they know and need to know. Costa suggests that this develops perseverance and enhances students' ability to create strategies that will produce desired outcomes.

Likewise, Hyde and Bizar (1989) suggest that the teacher instruct students to practice using a variety of metacognitive prompts as they learn the processes and to have the students practice the prompts in small groups. Such prompts are:

Have I ever encountered a similar problem?

What do they really want here?

What information is irrelevant?

Which of the strategies that I have learned will help me?

Teacher as a model

Schoenfeld (1987b) recommends that the teacher model how to think through a given

task, how and when to apply the strategies, and "what to do when you don't know what to do". The teacher becomes the metacognitively-aware problem solver who models the process of thinking by thinking aloud and asking students to think aloud about such things as the reasoning in solving a problem. When modelling metacognitive processing during the solving of a problem, the teacher routinely explains the solutions of problems by pointing out the importance of reading carefully, by discussing why a particular strategy was chosen, by openly checking the work, and by comparing the final answer to the conditions of the problem. Specific metacognitive processes that need to be modelled by the teacher and practised by the student are self-planning, self-monitoring, self-regulating, self-questioning, self-reflecting, self-reviewing, and self-evaluation.

In a research project which involved grade seven students solving three different types of problems over 20 days, Lester (1988) adopted the role of teacher as model. As the students became progressively more able to orchestrate the problem-solving process for themselves, Lester's contribution of cognitive work decreased. However, Lester indicates that the role of the teacher as a model may not result in the learning that is intended because of two inherent flaws. The first flaw lies in the reality that the problems are not real problems for the teacher and the students know this. Secondly, it may be difficult for the teacher to maintain the role of expert problem solver. The role of being the teacher may be too powerful and the teacher may begin to explain the question and guide the students through the problem solution, rather than model the metacognitive processing. "I am the first to admit this kind of modelling approach is artificial and must be used sparingly, for it wears thin pretty rapidly." (Lester, 1988, p.200)

Teacher as a mediator

In the role of mediator, the teacher coaches students towards independent learning. This scaffolding of the instruction is a process that enables a student to solve a problem, carry out a task, or achieve a goal which would be beyond his or her unassisted efforts. The teacher tries to elicit evidence of thinking from children by asking many questions which tend to provoke a processing of thinking rather than a content-oriented answer. The following are some examples:

> "What do you need to do next? Tell me how you did that? What do you think would happen if ... ? When have you done something like this before? Yes, that is right but how do you know it's right? When is another time you need to ... ? Can you think of another way we could do this? Why is this one better than that one? How can you find out? How is _____ different from _____ ?"

Guideline 3: Place overt and direct emphasis on students' self-control.

The teacher must place direct emphasis on students taking control and accepting responsibility for their own learning. Students can learn that self-monitoring is a valuable skill. They can learn to systematically develop commitment, a positive and personal attitude toward learning, and attention through introspection and practice. One approach to addressing metacognitive issues explicitly is to have the students note their level of commitment, attitude, and level of attention in mathematics journals (Azzolino, 1990). Students would be required to write in their journals a description about their commitment, attitude, and attention, as well as telling how their self-awareness affects their behaviour.

Guideline 4: Establish an interactive learning environment.

There is growing consensus that interactive learning environments which enhance students' conceptual understanding of procedures and confront the metacognitive issues directly, produce more insightful, intentional learners (Gavelek & Raphael, 1985; Campione et al., 1988). Good strategy instruction is interactive. Group work such as cooperative learning groups (Campione et al., 1988) may make metacognitive thoughts verbal and analyzable. Schoenfeld (1987b) recommended small group cooperative problem solving at the secondary level because he considered it to be especially conducive to fostering meta-level discussions and problem analysis.

Although presented separately, the four instructional guidelines are not independent of one another. When providing instruction to a whole class, small group, or individual student, the teacher must plan the learning activities and shift between the teaching roles as required.

Following his own teaching experience with grade seven students, Lester (1988, pp. 119-121) confirmed the need to shift roles and offered other suggestions for teaching metacognitive behaviour that are summarized below:

1. When working with grade seven students in problem solving, he found that they often lacked adequate conceptual understanding or were weak in certain skills. Because the students lacked the necessary knowledge, he had to spend time explaining the meaning of a concept or how to do a calculation, rather than discussing metacognitive-level considerations. He recommends that the

teacher should try to combine instruction in meanings of concepts and how to perform various basic skills with instruction in metacognitive awareness .

2. He suggests that the teacher can direct students to reflect upon their own cognition by completing self-inventory sheets on which the students list their strengths and weaknesses in doing mathematics. However, he found that many of the students do have considerable difficulty reflecting on their own thought processes. Some students were reticent about discussing their own capabilities and limitations because they viewed such activity as a threat to their self-concepts.

3. He suggests that metacognitive processing could be facilitated by showing students videotapes of students not from their class solving problems and discussing with them the good and not so good behaviours that they see. When students viewed others solving a problem, he noticed that they were quick to point out errors in the student's thinking.

Student Interaction in Small Group Work

The topic of using small groups is not a new one to educators. John Dewey (1902) recommended that children be encouraged to work in small groups because he believed that intelligence is developed socially. Mathematics researchers (Schoenfeld, 1985a; Lester, 1988) advocate the use of small group work for the enhancement of mathematics performance. Although cognitive growth is considered to be highly dependent on social interaction, educators are just learning about the conditions under which small group work enhances performance.

While most research presents a favourable picture of small group learning, not all reviews have concluded that working in small groups (also referred to as cooperative learning) is always beneficial for learning (Slavin, 1988). Successful small group work in the classroom doesn't just happen. It depends upon the degree to which teachers understand how to operate small groups, the commitment they have to their success, and the extent to which students regard working in groups as a significant learning strategy (Reid, Forrestal & Cook, 1990, p. 59).

Small group work can break down when conflicts and power struggles are not managed well. Students must be taught cooperative skills, must learn how to resolve conflicts, and must learn how to deal effectively with classmates who won't participate. Good helping behaviour is not automatic; it needs to be defined, modelled, and practised. For students to

work well in groups they must (1) get to know and trust one another (2) communicate accurately and unambiguously, (3) accept and support one another, and (4) resolve conflicts constructively (Slavin, 1988).

Although the importance of student interaction for enhancing learning is clearly recognized, there is little data provided to teachers about the types of interactions and student talk that best promote achievement. Small group work does not appear to be equally effective for all students (Webb, 1982; Allan, 1991). When planning for group work in the classroom what combinations of students provide optimum results? Webb (1982), Peterson (1985), and Allan (1991) found behaviours involving 'giving help on an academic task' to be most facilitative in group learning. Students who gave explanations of how to complete the task showed higher achievement than students who did not actively engage in group interactions. Webb (1982) suggests that students who are helping a peer may view themselves as a teacher and that preparing to teach someone else produces a more highly organized cognitive structure within the student than when the student is only trying to learn material for oneself.

Webb also studied the types of responses students received to their questions when they asked for help. The type of response they got from members of their group had an effect on their performance. Being supplied with the correct answer to a problem does not facilitate a student's learning, but being told why one's answer is incorrect may help the student's learning. Webb found that students in homogeneous groupings were less likely to have their questions answered than students in mixed ability groupings.

Allen (1991) reported that all children show positive academic effects from some forms of homogeneous grouping. Apparently students gain most from watching others of similar ability gradually improve their performance after some effort, rather than watching someone who can demonstrate perfect performance from the outset. Students who were ability grouped for a specific subject were found to have a better attitude toward the subject, but that grouping did not change their attitudes about school in general.

Webb (1982) suggests that small heterogeneous groups of low ability students and high ability students facilitate greater learning than large mixed ability groups or having students work on their own. Medium ability students do benefit from mixed ability grouping, but, it appears, not to the same extent as high and low ability students.

In heterogeneous groups, high ability or high status students appear to dominate group interaction, to explain more, and to be more influential, and they are more likely to be seen as leaders. Low ability students are most often the target of the explanations. Ideally, the interactions will offer low ability students enhanced learning support which includes other-regulation and an opportunity for more active learning.

On the other hand, if less able students have fewer opportunities to be the one who gives help, they may be deprived of the beneficial effects of giving. This may be a case where the rich get richer. Whether it is possible to plan lessons where the more capable partner will discuss mathematics with the less capable partner remains unanswered. Often,

leadership in mathematics is dependent on 'knowing the material', and for elementary children the ability range of students in a group may be too great for successful dialogue between these students.

Organizing Small Group Interactions

When planning for student interaction, the teacher may provide opportunities for informal interaction or use a more formal lesson structure that orchestrates specific types of student interactions. Many classrooms that incorporate cooperative learning into mathematics begin the lesson with a teacher directed segment and then have the students participate cooperatively on the assignments. In these informal settings students are given little direction in how they should cooperate. For example, students might be told to work together and check their answers with other students before asking for assistance from the teacher. These instructional programs place few constraints on students' choice with regard to the procedure for completing tasks and the extent to which face to face interactions of students are regulated. What matters to the teacher is to create a situation where students talk to one another, rehearse the material, obtain feedback on their understanding, receive information they may have missed or lacked, and restructure their knowledge by describing and explaining information to others.

A more formal approach to small group work is recommended by Johnson and Johnson (1988). Their model for cooperative learning requires positive interdependence, face-

to-face interaction, individual accountability, social skills, and group goals. Of these five elements, individual accountability and a group goal are essential for the academic effects of cooperative learning to be realized (Slavin, 1988; Johnson and Johnson, 1989).

Johnson and Johnson advocate that problem solving achievement is increased by implementing a highly structured cooperative learning method that often involves the assigning of roles to the students. Ross and Raphael (1990) have provided evidence that this formal approach is not needed, at least in the elementary grades. They examined communication in highly structured and unstructured cooperative groups. In the structured cooperative classroom, students were assigned to specific roles within their groups and the roles were rotated among members at the end of each session. Activities such as praising students, praising the task, and criticizing the task all increased in the unstructured classroom. In the structured classroom fewer questions and other requests for help were made, and the number of contributions declined substantially over time.

Also, in the Ross and Raphael (1990) study the highly structured class did not achieve as well as the unstructured group. Whether this was due to the students being overloaded by the demands of the assigned roles and procedures being combined with the demands of the learning task is not clear. It is not clear if the role assignments and procedures led to deteriorating motivation or if the excessive practising of the roles reduced spontaneity and caused the tasks to become boring. It does raise questions about the suitability of Johnson's model for students under the age of twelve.

Some researchers (Johnson and Johnson, 1990; Slavin, 1988; 1991a; 1991b) argue that group rewards are necessary for students to take one another's achievement and contribution to the group seriously. Group goals are said to be necessary to motivate students to help one another learn, to help students overcome their reluctance to ask for help, and provide help to one another. They may stop one or two of the group members from doing all the work. Group rewards have been instructionally effective when the assignment of group grades is based on the average of group members' individual quiz scores. According to Slavin (1991b) cooperative learning simply focuses the classroom reward system on helping others learn (as well as on one's own learning).

Educators that question the necessity of group rewards say that the perils of using rewards to bribe students to work together include decreased motivation and lower levels of performance. Research in social psychology has shown that rewards are not only surprisingly limited in their effectiveness but also tend to undermine interest in the task (Kohn, 1991a; 1991b). "In terms of motivational power, no artificial inducement can match the strength of intrinsic interest in a task" (Kohn, 1991a, p.83). "If the task is challenging and interesting, and if students are sufficiently prepared for skills in group process, students will experience the process of group work itself as highly rewarding" (Kohn, 1991a, p.86). Graves (1991) further argues that achievement comes chiefly from giving students more control over their learning, not from waving a gradebook at them.

Summary

Giving students control of their own learning and making them successful independent learners is the driving force behind the inclusion of metacognitive processes in classroom instruction. Various theories about when and how children become aware of their thinking and when and how they learn to manage their thinking have been given. The development of metacognition varies in children. According to the theories, the children with learning disabilities and those who are weak academically do not have the same access to metacognitive processing as academically successful students. Children who are deprived of mediated learning experiences are slow to develop the structures and regulatory activities necessary for metacognition. If it is true that metacognition is developed through social interactions that provide mediated learning experiences, then classroom teachers need to consciously provide small group activities that can maximize the academic benefits found in social interaction.

The classroom context that best provides for metacognitive training is not clear. Whether a formal or an informal approach to small group work should be adopted remains a controversy among educators.

If children at age eleven are capable of metacognition, then the classroom teacher needs to provide instruction that will help the children 'learn how to learn.' The children need to acquire strategies for planning, monitoring, and evaluating their learning. In the

mathematics classroom this can be demonstrated by their ability to understand, plan, solve, and evaluate their solution to a mathematics problem. Instructional strategies for developing metacognitive processes have to focus on ways of getting children to become more aware of the influence of their thoughts (self-talk) on attitude, commitment, and level of attention. Children need to become active rather than passive learners.

Chapter 3: Implementing Metacognitive Processing

Theories on metacognition and instructional strategies for teaching metacognitive processing were implemented in a grade six class taught by the author. The author enjoyed teaching mathematics and felt confident about structuring the mathematics program and lessons to include a consistent focus on metacognitive processing. As the author was not this grade six class's homeroom teacher, the contact between teacher and students was limited to the scheduled mathematics classes. The rapport between teacher and students, the personalities of the individual students, and the school instructional organization played a role in how the theories were put into practice and in the evaluation of the practicality of these educational theories for this grade six classroom.

The Setting

The study was carried out at Lord Selkirk Elementary School, a large, crowded, inner-city school located in a low economic area of Vancouver. Seventy-five percent of the 650 students learned English as a second language and continue to speak one of thirty-five first languages at home.

Among the 33 grade six students to whom I taught mathematics, 22 spoke a language other than English at home. Five students from the Intermediate English as a Second Language classroom were integrated for mathematics. These students knew little English.

The mathematics class had a wide range of abilities. From the Public Progress Cards their grade five year end averages were: four A - standing students, eight B - standing students, two C+ - standing students, five C - standing students, seven P - (below grade level) students and seven students with no grade average as they were new immigrants to Canada. Of the seven with P standing, two were identified through district testing as being learning disabled and were unable to participate successfully in mathematics activities involving problem solving and number operation. They participated with the class for measurement, data analysis, and geometry activities.

For mathematics, the children received four 33-minute periods and two 40-minute periods. Since the children were platooned for mathematics, their mathematics instruction took place in various settings. Four of the classes took place in the lunchroom which was located in the basement of the school and which they had to share once a week with a grade seven class. Two of the classes took place in a grade five classroom while that class was at gym. Since I was the school's vice-principal as well as the grade six mathematics teacher, there were occasions during the principal's absence, that lessons were interrupted while I addressed administrative concerns in the office.

The mathematics curriculum followed the content requirements as mandated in the British Columbia Mathematics Curriculum Guide (British Columbia Ministry of Education, 1987) for grade six students. In September two periods per week were assigned to introducing problem solving strategies. The Houghton Mifflin problem solving booklets (Szetela, Super, & Seidenberg, 1982) were the main source for non-routine problems. The systematic focus and

systematic focus and practice on problem solving strategies which occurred on Tuesdays and Thursdays was cancelled at the end of October because I felt the students needed daily practice on developing concepts and skills in multiplication and division of whole numbers and decimal fractions. The double periods on Monday and Friday were frequently cancelled because of Professional Development Days, school holidays, and assemblies. Throughout the year thirty-one lessons were cancelled.

The most frequently used lesson format had four parts. While waiting for the lesson to begin, the students compared the answers of their homework assignments with their partners (five minutes). This was to help them shift from their previous class's activities and settle into the mathematics class. It helped to remind them what the last mathematics class was about. The lesson would begin with three to five quiz questions based on the last day's work. They were to do the questions first on their own, then talk the solutions over with their partners. The questions were then discussed as a class (five minutes). The new skill and mathematical vocabulary that they were to focus on was written on the board along with the possible homework assignment. A teacher directed lesson or planned student activity would be presented (10-15 minutes) followed by guided practice on homework assignment (10 minutes). Before doing the guided practice the students would look over the assignment with the teacher and discuss the purpose of the various types of questions. They would know the purpose of each practice question and be asked to think about what they understood from the lesson and identify for themselves what they needed to understand better.

In order to provide for individual accountability, I collected and marked their notebooks three times a week. Students with a habit of not completing assignments were asked to complete homework prior to going home. They would remain in their classroom from 3:00 - 3:30 and be monitored by either their homeroom teacher or myself.

The Focus on Metacognition

For the school year 1990-91, I wanted to focus on three aspects of metacognition: reflective access, self-regulation, and executive control, and on ways to provide other-regulation. My goal was to facilitate the development of metacognitive processes in the children, the belief being that eleven year old children could become aware that they were capable of influencing their commitment to learning, their level of attention, and their attitude towards mathematics. I would explain to the children various ways that I thought they could use in order to regulate their learning activities and become independent learners.

Journal Writing

In order to facilitate the development of metacognitive processing, I incorporated the teaching strategies and the four guidelines described in Chapter Two. Students were asked to reflect on lessons and to identify for themselves what they had learned and what they had not understood or still needed to practice. To help the students summarize, organize, and relate their ideas to themselves, they were required at the end of certain lessons to record their thoughts in their mathematics journals. In order to help the students who were not sure what

they should write about, I would write three or four questions that they could answer. It was the intention that the journal writing would help students see that they played an active role in their mathematics learning. Journal writing would demand participation by all students and assist them in reviewing their understanding or progress in mathematics. I was aware that they wrote response journals in their literature-based reading programs, and was careful to plan when they would write in their journals (before beginning a new topic, midway through a unit, before an exam, or after using a different teaching strategy) rather than doing it daily. Fortunately, this class was not involved in a daily diary for their classroom teacher or journal writing in the mathematics classroom might have met some resistance.

Textbook as a Resource

I explained to the children how each lesson in their textbook (Connelly et al., 1987) was organized into four parts and the purpose of each of the four parts. They were taught how to use the index and dictionary of mathematical terms found in the back of the textbook so that they could use the textbook as a reference book. When they came to a mathematics concept they had learned earlier in the year but had forgotten, they were expected to look back into their textbook for a reminder.

Identifying Levels of Understanding

Children were reminded they could influence their achievement by focusing their attention on the lesson and identifying what it was they didn't understand. Then they knew if they were ready to practice what they had learned or whether they still needed assistance on

understanding the concept. The children were told that they were not to use the expression, "I can't" because it often means "I'm too lazy to try." Students for whom the lesson might be a review were asked to see if they could predict the questions the author might ask next or if they could explain what the class didn't understand in a different way.

Interactive Learning Environment

In order to facilitate the development of metacognitive skills through other-regulation, I focused on developing an interactive learning environment through daily small group work. In order to increase the social interaction between the children, the children had new partners every three weeks. Later in the year, the children did not change partners as frequently. Reasons for this decision will be explained in the following chapter. The children were initially paired according to their mathematical progress scores from grade five. The A and B level students were paired, B with C level students, and C with P level students. The English as a Second Language students were paired according to their mother language or established friendship.

To encourage metacognitive processing through mediation between the children and the teacher or between children and their peers, the lessons were structured to encourage group work. The lesson would begin with the children comparing their homework assignment with their partner. When partners had different answers to their homework questions, they were required to look back into the textbook to check the questions that were assigned and find the copying mistake or misunderstanding that had been made. The value of checking out

why answers were different was stressed. They were told that they often learned more when doing corrections because it made them think about what they had done. To ensure that the students marked their work accurately, I would collect and check all books. When the work had been incorrectly marked, the children had to stay in after school and work on corrections.

Teaching Executive Routines

Executive routines of planning, monitoring, assessing were taught through the use of Polya's problem solving model. Although research does not provide evidence that practising a strategy improves strategy use in the problem solving process, I felt that strategy practice and extended social interaction between child and teacher, child and parent, child and friend during problem solving might facilitate strategy use and problem solving achievement.

My role during lesson time was to model self-talk, emphasize the language of mathematics, introduce a variety of questioning strategies, link new concepts or tasks to previous lessons or the past year's work, and provide a framework for organizing problem-solving experiences. Instruction on the Polyan model was explicit. The students had to present their work in the following format:

1. Think: Write a phrase telling what it is you are asked to find. Make a list of the information that will help solve the problem. Tell if you have solved a problem similar to this before.
2. Plan: Write a plan of what you will do first and how you will do it. Tell what you

will do next.

3. Do: Show all your working.

4. Look Back: Write the answer in a short sentence. Check your answer with your partner. Did your partner think about the problem in the same way?

The problem solving strategies that were taught included: act it out or picture it in your mind, draw a picture, make a chart or a list, and look for a pattern. I placed great emphasis on understanding what the problem was about and locating the needed information. This was especially important for students who did not know expressions such as "picket fence," "round robin tournament," "half time," "double time," "in sixes," "in stacks."

I had the students solve problems alone or with a partner, and then, in groups or as a whole class activity, identify all the different ways the class had used to solve a specific problem by writing their solutions on the blackboard or chart paper.

In summary, my organization for the mathematics program involved setting aside time for journal writing, clarifying the purpose and value of assignments, and having students reflect about their progress in mathematics. I concentrated on using more small group activities than whole group activities. The following chapter presents the challenges that I faced and the adjustments that I made to accommodate the metacognitive goals within the grade six mathematics program.

Chapter Four: Reflections on the Implementation

The focus of the mathematics instruction from September 1990 to June 1991 was the integration of metacognitive processing with existing teaching strategies. Some of the cognitive and metacognitive strategies that were described in Chapter Two had not been introduced in classroom settings but instead were used by a researcher with a small group of students (Peterson and Swing, 1985, p. 17). This chapter assesses the effectiveness of instruction designed to promote these strategies among grade six students. The chapter is organized in two sections: the effects of small group instruction and evidence of metacognitive development.

Effects of Small Group Instruction

Engineering the social interactions between students proved to be the greatest challenge for me. In September, the students were told that they would be doing much of their class work with a variety of partners over the year. The advantage of this would be that they would have the opportunity to see the different ways that mathematics is done by other students and they would get to know their classmates better. They would have a partner for about a month and then change to a different partner. On September 19, when the students' names were read out many ridiculing comments were made and some students refused to sit with their partners. This mathematics class became a social skills lesson requiring a discussion of how people like to be treated, and ground rules were set on how students would

treat one another in the class. Put downs would not be allowed. They would work with their partner and focus on what their partner was able to teach them about mathematics and ways that they could help their partner.

At various times in the first three months of the school term, the students were asked to write their reactions and thoughts related to working with a partner in their journals. The journal comments made me more aware of the children's perceptions about group work, their insights about their similarities and differences as learners, and the empathy that they had for one another. The following are comments written in their journals:

Maria (C average in mathematics; a very capable student in language arts; highly motivated):

> Today I got a new partner. Jeffrey is smart so I don't really mind except last time I had Vicky and she's nice but we're on different levels in Math. I think that we should be put into separate groups by our skills. You may think that makes some people feel bad but just think how they feel when you put them with a smart person and they get all their answers wrong and their partner get's them right. (Sept. 24)
>
> This week Amy is my partner. I don't mind even though some people say 'I feel sorry for you'. I think Amy is good at math but not responsible for herself and as you say her learning. The reason I think I'm improving is because you have taught me how to teach myself. (Nov. 15)

Maria's comments of Sept. 24 made me more sensitive to the children's need for self esteem and suggested to me that grouping heterogeneously did not necessarily provide better mathematical support for the less capable partner. I became more aware that the partners that worked best were those of similar ability or who were working with their best friend.

Maria's comments of Nov. 15 are an example of the children's acknowledgement that I expected them to accept responsibility for their learning. Learning to learn strategies (textbook as a resource, study skills) were actively used by some students. Maria had been paired with a challenging partner and did her best to counteract Amy's antisocial behaviour.

Calvin (B average in mathematics; Chinese as his first language):

> My new partner is sometimes wrong about an answer and she get mad. But I tell her don't get mad, sometimes I'm slow too. My old partner was smart and was wrong. Sometimes he's slow too then I'm slow. But my new partner is okay. (Sept. 24)

Calvin's comments reinforced my opinion that students could influence one another's attitude towards their work and in this case help build tolerance for the challenges of mathematics.

Comments similar to Christina's and Sonny's that follow below had me questioning my decision to assign partners according to ability and for the purpose of helping students to get to know other classmates better. There were social cliques in this class and it took too long for some partners to feel at ease with one another. The children were compliant with my decisions and felt comfortable to tell me they wanted a change to the grouping practice.

Christina (C average in mathematics; conscientious with parental support):

I think having a partner is good. It's better than working by yourself, if you make a

> mistake they help you and you help them. And you also get to know the people in your class better. But I think we should pick our own partners. (Sept. 24)

Sonny (C average in mathematics; Chinese as first language; anti-social behaviour; low self-esteem):

> Today I learn that my partner is nice and he like to move his head up and down and he writes smaller than me. And he bugs me like a pest. (Sept. 25)
>
> Why do I have to have the same old partner? I don't know why I have to have this partner. I don't even like his looks, head, and the fact that he's a boy. Oh yeah, and the way he acts. Problem solving is hard. (Oct. 05)

On November 30, while still struggling with the social dynamics within the class, I asked the students to evaluate whether they thought they worked well with their partner, and if they did, could they tell others what made it possible for them to work well together. As the students made their responses, the teacher recorded them on the blackboard. One team's response was, "We know one another." My comment was that they all knew one another as they had been partners for three weeks. The response to this was, "That's not really knowing someone."

This comment reminded me of one of the requirements for successful group work - trust. Changing groups every three weeks was not allowing enough time for students to get to know one another and develop rapport and respect. The commitment needed to help each other learn mathematics may be stronger between students who know and like one another than students who are uncomfortable with each other. These students were only working together in mathematics periods and returning to established friendships in their homeroom.

Influenced by journal comments and a desire to lessen social conflict, I decided in December to pair students in homogeneous groupings. At this time the decision was made to have the children keep the same partner for three months and see if this would improve the tone in the classroom. However there were a few exceptions to this decision. The three students who had not worked well with partners, who did not have friends in the classroom, and who would harass other students by kicking, taking possessions, and writing comments on other students' books, were left to work on their own.

When making the final partner assignments in April, I considered existing friendships as well as mathematics ability. There was not enough time within the math class to deal with the many social challenges presented. I had noticed that the three students who had trouble initially with partner work gradually attached themselves on an informal basis to existing partnerships whenever they wanted to receive or offer help. By the end of May, all students were working cooperatively in small groups.

I was aware that the Johnson and Johnson model (1988) for cooperative learning that was supported in the Vancouver School District required careful orchestration of student interactions. Although I was having difficulties with certain students' social skills, I had not been focusing on developing specific social skills that were considered necessary for successful group work or building group goals into my class's small group work. I became concerned that my lessons needed to be more structured. So I decided that at least one mathematics unit should be structured according to the formal model, and in March a unit on

common fractions was organized. The unit began with the partners working on the chapter posttest. This was to help them identify what they remembered from their grade five work and to become aware of what types of activities they would become involved with over the next three weeks. The students were allowed to use the textbook and knew the test would not be marked. The test would be returned at the end of the fraction unit and they could complete and correct it.

For this unit of study, I decided to have the students form groups of four with each group's goal being to make sure everyone in their group understood each fraction lesson and was able to successfully complete the assignments. Instead of marking every student's notebook, I would mark only one partner's notebook and this mark would be the mark for the whole group. They wouldn't know in advance whose book would be collected. On the mini-tests, their mark would be the average of the group score.

On the due day of the first homework assignment, I found that eight students had not completed their homework. To penalize partners because of their partner's work habits was not an acceptable position for me to take, so grading according to one student's work was not implemented. I found that the students socialized more in the groups of four and were slower getting down to work. With such short mathematics periods, they soon had more work to complete outside of classtime. Their journal comments indicated that they resented the amount of homework they started to have, and that they knew the homework was given because they were not focusing on their assignments in classtime. Since I wanted to maintain

a positive tone in the mathematics classroom and was feeling the pressure of time constraints and curricular demands, I reverted back to the informal lesson structure for group work. Partners of two seemed to function best.

Interactions within groups (giving help, receiving help, and responses received for assistance) were monitored informally. The pressure of pacing the mathematics content through the year and of providing extra assistance to students who were slower to grasp mathematics concepts often did not allow much daily personal interaction with some partners. Most of my awareness of what occurred between students comes from reading the students' journal comments. Through the journal responses I was able to reinforce positive partner interactions by writing short comments or speaking to the students privately. I noticed that students were able to mediate learning for each other. Some examples from the journal writing follow.

May (B average in mathematics; Chinese as her first language):

> When I worked with Doreen, I learned some things from her that I didn't know before. Most of our answers were right, and when one of us got an answer wrong, the other would help. (Sept. 24)
> I like working with Julia because both of us do equal share of work. We work together and try guessing and testing until we get the right answer. (Oct. 05)

May worked well with her partners in a peer tutoring relationship. Her partners and she were frequently discussing and helping one another as they worked on assignments.

Jeffrey (A average in mathematics; appeared bored with mathematics):

> This week I learned always prove your answer. My partner showed me to think hard at a question. He also showed me not to rush. (Oct. 12)

Jeffrey wrote very little in his journal and frequently expressed that he knew how to do everything. I found this comment quite a surprise in that he acknowledged that he had learned something from his partner and needed to make some adjustment to his work habits.

Vickie (C average in mathematics; positive attitude):

> I learned to do the problem, to do subtraction and me and Sabrina know about the same things in math but she knows more. She understands more than I do. She's fun to work with. She is like a teacher to me because she shows me how to do things in math. I like working with her. I learned to depend on yourself, believe you can do the work that you give us and so I do and I am getting to know how to do math. The better I am coming in math I am getting to like it. I still need to learn my times tables. (Oct. 05)

These partners had a difficult time learning mathematics but together they were able to succeed and improve their self-esteem. They formed a close friendship while working together which lasted after they changed partners.

Matt (B average in mathematics; easily discouraged):

> My partner has weaknesses that I don't have and I have weaknesses that partner doesn't have. I learned different things this week such as rounding decimals, subtracting decimals and lot's more. My partner showed me how to work out problems in an entirely different way. (Oct. 05)

Matt benefited from working with partners as he realized other students could not do

everything perfectly either and that together they could learn. He gradually became less down on himself.

It was journal comments such as these that encouraged me to continue emphasizing small group work. As the year progressed it became strikingly obvious that the journals permitted a personal rapport with students that might not otherwise occur. Through journal writing, children, like Tom, confided in me and shared significant secrets.

Tom (D average in mathematics; Tagalog is his first language; parents in a custody battle):

> To Williamson, I kept this secret for 3 years. When I was in old school in grade 3 we didn't do much of dividing and multiplying. We did a lot of subtraction and addition and when I move to this school they were starting to multiply and divide but I didn't know that much. I didn't say anything to the teacher because I was too scared to. So I copied. I hope you can spend some time with me and teach me how to do multiplying and dividing. Please don't tell anyone because they might think that I'm stupid. If you have extra time can you help me? Please don't tell anyone. I just want to be smart as the other students. (Nov. 10)

I had felt that Tom was unable to multiply and divide but all his work was correctly done and on quizzes he was successful. However, on exams that I supervised, he failed. Whenever a substitute gave an exam, he passed. Tom had formed friendships with two A - average students and they supplied him with answers. Even when he was provided a tutor, he was unable to acquire the skills. It was not until the month of May that during classtime he would leave these two students and join me and several other students who wanted help with problem solving. Although I was unable to help him learn to multiply and divide, with the aid of the calculator he was able to be successful in problem solving activities. However, he

would not accept extra help from me outside of classtime and continued to cover up his disability with great skill.

Christina (C average in mathematics; conscientious with parental support):

> I learned how to do volume and area better than I did. My work is not good because I don't understand it. I need more help but I'm scared to ask because the other kids will laugh at me. (Feb. 19)

Christina wrote these comments when the class was working in groups of four. Prior to this she had felt confident in asking her partner for assistance, but the social dynamics between her and her partner changed when they were in a group of four. It was only through the journal writing that I would know of Christina's concern and be able to provide her with extra assistance. These social dynamics also reinforced my decision to return to groups of twos.

It was a challenge trying to meet the individual learning styles of the students. During journal time the students were asked to write if there was anything that I could do to help them learn better. I wanted them to reflect on what they needed in order to learn well. Comments such as the ones that follow prompted me to adjust my instruction. However, letting some work ahead with their partners resulted in work incorrectly done and frustration that it had to be redone.

Maria (C average in mathematics; A average in language arts, science and social studies):

> I now know fractions inside out so there's nothing else you can help me with. I think you sometimes over explain things so by the end of the lesson when we start to work it's forgotten. I think you should explain once then say whoever knows it can go

ahead and whoever doesn't could keep watching the lesson. (April 16)

> This week we have been able to go on in the math book and I think it's better that way. Now we are not wasting time on lessons we already know. (April 19)

I did adjust my instruction so that I could work more closely with those who needed extra help and was surprised to find that it took until the month of May for many partners to feel comfortable in admitting in front of their peers that they would like to receive further instruction on a lesson.

Kevin (B average in mathematics; Chinese as his first language; highly motivated):

> I've studied fractions for the last two weeks. I learned fractions by times-ing the denominator and looking at the numerator. I'm starting to improve every minute in fractions. I have no problems. I just make silly mistakes but I really understand it very well. I understand the work we did for the last two weeks. It was very simple after you gave a good lesson that helped a lot. Most people think it was boring but I don't think it was boring. I learned so much from you in math. (April 16)

Kevin's comments made me feel good that I was having success with one student but concerned that others were bored. These comments made me reflect upon what was happening in class and lessons were adjusted in order to better meet the needs of certain students.

A number of students were resistant to journal writing, and only by emphasizing its importance could I make the students settle down, reflect, and write in their journals. In order to get all students to reflect on the questions regarding their progress, all mathematics activity

had to be stopped, mathematics books closed, journals handed out, some possible questions to answer written on the board, and a timer set for 5 minutes. The students wanted evidence that I had read their journal and looked forward to reading my brief comments. To read and comment on the journal entries took me about an hour to an hour and a half. Daily journal entries were unrealistic because of time needed to bring a lesson to closure and the fact that the children were involved in reading response journals in language arts, and so journal entries were made about every two weeks at the end of a Monday or Friday double period.

Evidence of Metacognitive Development

The prime reason for journal writing was to have students realize they can influence their learning and attitude. The following are some journal entries that show that students at age eleven do participate in self-talk and are influenced by other-regulation.

Matt (B average in mathematics; easily frustrated):

> I think I'm doing better than I did last week. My mom showed me that I can do something if I have patience. And Ms Williamson showed me that division is easy if you know how to do it. My mom also showed me how to check my answer by using multiplication. (Nov. 15)

> I learned when the test is on dividing decimals I should have faith in myself. I kept on saying to myself I can't do this but I did. (Nov. 30) I have been working on the 4 steps of problem solving. It is easy for me. I need to focus on my work and not get down on myself. I would like a new partner. Jeremy does not focus and it is hard to work. (May 15)

Matt's comments demonstrate the influence of other-regulation by his mother and myself on his learning of mathematics and on his attitude. He demonstrates self-regulation in that he knows he needs to stop getting down on himself and that his partner is hindering his ability to concentrate and achieve his goals.

May (B average in mathematics; very quiet):

> Sometimes when I can't solve a problem I get frustrated and I start saying stuff like "I hate math" or "Math is stupid." Most of the time I think math is boring. If I complained to my mom she would probably say that math is an important subject and things like that. (Feb. 04)
>
> When I can't solve a problem I start to get frustrated. I feel as if I want to tear up the book. Problem solving means that if you have trouble deciding something, you have to use the think, plan, do and look back method. I don't like problem solving, it is boring. The think, plan, do and look back method is too long to do. There are lots of steps. I just like making a chart or pattern. It is faster that way. (May 02)
>
> When I do a problem and I think its hard, I would want to skip it or do it for homework. I don't like problem solving. Sometimes I get bored with the problem that I'm on. (May 23)
>
> Some problems on p. 32 are easy. Some are confusing. I think I am beginning to like problem solving. Sometimes I think that a hard problem is kind of like a challenge. The plan stage is really not important. Sometimes when I'm stuck on a problem, I read it over and over again. I try to imagine a picture. (June 06)

I had written many comments in May's journal supporting the importance of mathematics, stating how successful she was in mathematics, and acknowledging that I also felt frustrated at times and would stop working on a problem for a while and come back to it later. Over a period of time I could see May demonstrate more self-talk in her journal, and

develop a more positive attitude towards problem solving.

Jennifer (B average in mathematics; top academic student in her class):

> I have been learning a lot because we always try different things to learn better. It's also fun. I think that working with a partner is better than working individually. When I work with my partner, she tells me what I've done wrong, and I tell her what she has. This way, the next time we work, we remember each other's words, and work better. (Jan. 25)
>
> The mistake I find myself doing all the time is 6 plus 3 equals 8. I always get mixed up. Now, I'm going to get my brain organized and switch my thinking to 6 plus 3 equals 9. Sometimes when I'm doing that now, I catch myself. (March 08)
>
> I feel good about my mark on the test. I also understand what I've done wrong on my test. To me problem solving means problems that need to be solved by multiplying, addition, and division. I think that my ability isn't poor and isn't excellent. I think I am just so-so. If I find a problem that I don't understand, I usually ask my brother, father, or a teacher. (May 02)
>
> I understand problem solving now more than I knew at the beginning of the year. I learned that I understand a problem more every time I read a problem. Some problems mix me up when it has more information than is needed, too. I need to focus more on gathering all the information I need to solve a problem. (May 23)

Of all the students, I felt that Jennifer's journal writing best demonstrated metacognitive processes (reflective access, self-regulation and executive control) in action. She was aware of areas where she could easily make mistakes, she disciplined herself to check her work and set goals, and she was aware of her progress and was responsive to the different ways of learning suggested by her partners and myself. She was aware of her level of commitment, attitude, and attention.

A focus on metacognitive processes was expected to improve the mathematics performance of weaker students more than for the average and bright students (Marazano & Arredono, 1986). Reflecting back on the students' progress, I did not find this to be the case. Students that were learning disabled did not improve their computation skills, even with extra support from a learning assistance teacher. A learning disability in short term memory skills was not overcome through a focus on metacognitive processes in a regular classroom of 33 students. Perhaps if the students were to work in a one on one situation with a teacher, they could have acquired the planning and monitoring skills they need, but in the regular classroom these cannot be provided with enough individual attention. The following are journal entries from one of the learning disabled students.

Jane (learning disabled student; Vietnamese is her first language):

> I think cutout is the best for me to learn and help me do my division and I think I learn a little better. I try hard on my division and multiplication and I can't do division. I need some help. I need more help and someone willing to help me. (January 25)

> At Mr. Temple I learn a lot of Math and with Mrs. MacKenzie I learn how to do subtraction and addition. I didn't really learn much about multiply or division. Can I have more time with Mrs. MacKenzie because I don't know what the class is talking about in math. (May 23)

> I have nothing to say about math because I don't know what to say. I can't come that much. I know I am bad at math and I am the only person that is bad at math. (June 10)

This student's frustration and awareness of being unable to succeed were reported

frequently in her journal. Because she was interacting with three teachers for mathematics and becoming a casualty, plans have been made for her 1991-92 program to be solely under the supervision of the special education teacher. Jane had the desire and commitment for learning but in mathematics met with little success.

Students who were unfocused learners (unable to concentrate on classroom activities) due to emotional trauma from family upheaval or abuse, and students who were spontaneous or hyperactive made little change in their level of attention and commitment. Their emotional and social needs interfered with their ability to reflect on their learning and focus their attention towards achieving goals. Some of these students were aware of their lack of focus and the effect it had on their achievement as shown in Jim's journal writing.

Jim (D average in mathematics; unfocused):

> I did not do my keeping sharp for homework so on the weekend I should do it anyways for practice because I have homework anyway. I like section in math we're doing now but I have to stop fooling around and start listening better because I have a little bit of problems. (Nov. 4)

> In my math I think I could do better if I focus on the lessons like you said. Problem solving to me right now means different things. About my ability for problem solving isn't very good. If I find a problem I don't understand I ask my partner or my mother to explain it. (May 02)

> In problem solving I've been doing charts about think, plan and do. I think plan is the easiest. I'm progressing pretty good. I think I need to focus on staying in the classroom. (May 16)

> I learned some problems are easier if I read them once or twice. I need to focus on

not having a partner because I want to work by myself. (May 25)

I think I'm coming better at problem solving because I don't get mad and fool around in class. (June 13)

Jim had the best intentions of completing his assignments and wanted to do well but could not discipline himself to ignore what all the other students were doing in the class. He saw himself as having a strength in problem solving and this did much to improve his work habits, attitude and self confidence in mathematics. He chose to work on his own for most of June.

The instructional strategy of modelling problem solving processes and demonstrating how to think out loud did not prove to be successful. As soon as I began to talk, the same four or five students would become unfocused and tune out. These were students who had a good command of English. In order for them not to tune out as soon as I began to talk or began a class discussion, my lessons needed to involve activities such as: "Write down what you think the answer might be. Share it with your partner. Now, let's share your answer with the class." They needed to be actively involved at all times. Frequently when the class began assigned practice, these students raised their hands and commented that they did not understand the work that was assigned.

When reflecting upon the students' progress, I formed the opinion that the students with average and above average ability received more reinforcement for how they were

learning because they successfully completed more assignments. Students such as Jennifer, May, and Marie showed that they could reflect on what it was that they were successfully doing and could handle difficult problems in a positive manner. But other students who were reluctant to complete assignments had less opportunity to see if anything that they were asked to try helped them to succeed. These students were aware of what they needed to do but for various reasons could not follow through, as the following example shows.

Amy (C average in mathematics; unfocused; social isolate):

> When do we change partners? Oh, before I forget I forgot my division that's why I didn't do the Keeping Sharp. But I still know the long division though. (November 30)

> I'm sorry that I hardly ever hand in sheets but I leave them in class, forget them at home and when I do them at home my mom takes them to mark and forgets to give them back. (March 19)

> I have learned a little but I'm very slow at working. But I still need help. What I need is more time to do the work. I don't get it done at home. I need time at school. At school I get work done. At home I don't. (May 16)

Although Amy was, in the opinion of all her teachers, a 'bright girl,' she made little progress in her academic subjects because her work was seldom done. The educational challenge for me was to find ways to help students such as Amy to access metacognitive processes and improve their academic learning. I have considered that classroom learning may not be suitable for all students. How I can access their preferred style of learning is a question that goes beyond the scope of this paper.

As the school year came to a close, I was pleased with the benefits of having students work with partners. The journal entries not only supported the theory that mediated learning can occur in small groups, that children of age eleven and twelve are capable of reflective access, self-regulation, and executive control, but they also allowed me greater personal rapport with the students and gave me feedback on my teaching. I found that even when I gave specific questions for the students to answer in their journals (e.g., 1. How did you feel about writing the test? 2. How might the test help you understand what you are to learn? 3. What did you find out about how you learn or what you remember about fractions?), they varied considerably in their ability to verbalize an answer for the reflective type of questions. The following excerpts illustrate this.

Vickie (C- average in mathematics; good work habits, demonstrates little ability for reflective access and self-regulation):

> I only know 4 questions on the test. We didn't do much fractions last year. I thought the test would be easy. We mostly did division last year.

Jennifer (B average in mathematics; highly motivated; Chinese is her first language, strong on reflective access and self-regulation):

> From last year I remember how to switch fractions but I don't remember how to add or subtract them or to work with something like this 7 4/12. I think the test helped me remember a lot. I'm starting this chapter with a goal of knowing fractions inside out by the end of the chapter. I think reading over instructions helps me remember things. It sometimes take a while for it to come back. My brain just has to click and all the information comes back.

May (B average in mathematics; Chinese is her first language; very quiet, demonstrating some reflective access and self-regulation):

> Sometimes I get confused because the fractions have numbers and I'm not good at

finding the lowest terms. Last year Mrs. Janzen gave my class a fraction booklet. We learn about equivalent fractions and adding fractions. Now I forgot how to find the equivalent fractions. When I get confused, I draw a picture and try to get the answer. When I wrote the test I feel sort of mixed up, so I looked in the textbook.

Jonathan (C average in mathematics; second year in Canada; Chinese is his first language; highly motivated, demonstrating some reflective access and self-regulation):

> In my country I know all about fraction and when I come to Canada I can't do the fraction because I forget it. I don't know it but when I look at the textbook then I remember it. But I remember some of it. I feel very scared when I write the test. The test help me learn by thinking it in my brain.

Whether or not I was able to facilitate the development of metacognitive processes in my students is not completely clear, but they were exposed to a year of self-reflection and self-talk that they might not have had the opportunity to experience.

Chapter 5: Summary and Conclusions

The purpose of this paper is to examine the implementation of theories about metacognition in a grade six classroom. Through an emphasis on journal writing the children were provided time to reflect on their mathematics achievements and to identify what cognitive actions they had used when they successfully solved a problem or understood a new mathematical concept. As the researcher it was my hypothesis that students' awareness of this meta-knowledge would have a positive effect on their next day's cognitive actions. As the teacher, I wanted the students to focus on how they learned, to understand how others learned and solved problems, and to realize that with perseverance they could effectively access many strategies. By providing for metacognitive experiences that could facilitate other-regulation, such as problem solving with a partner, I hoped that the students would take control of problem solving strategies and use them more effectively.

Prior to the implementation of teaching strategies that could facilitate the development of metacognition in grade six students, I had identified seven questions that were the impetus for this major paper and for the adjustments made to my instructional strategies during 1990-91 school term. At this time, each of these questions will be restated and answered on the basis of my experiences.

Question 1. Can children of age eleven be taught metacognitive processing?

Children at age eleven have varying metacognitive abilities. The instruction focused on

having the students identify and develop processes which could perform a management function of looking after knowledge which otherwise would be stored and remain dormant in contextual networks. As the teacher, I played an active role in helping students' link new mathematical knowledge to prior mathematical experiences and transferring this knowledge to new mathematical experiences. Students were taught to see the similarities between situations and to have the confidence to see mistakes as opportunities for new learning.

Executive control was emphasized. The students were guided to see that their learning was highly dependent on choices that they made. Their parents, teachers, and friends were sources for knowledge that they could use to guide their decision making. Students that appeared to access metacognitive processing the best were those who wanted to do well in their school studies.

Those students who appeared not to be interested in their achievement and had difficulties concentrating on their lessons, often did not like journal writing, working with partners, and had inconsistent work habits. They did not benefit from instruction in metacognitive processing in large group instruction. These students tended to demand more teacher time for their antisocial behaviour and had difficulty functioning in a regular mathematics class.

Many of the research studies involving metacognitive processing (Brown, 1987; Campione et al., 1988) involved the researcher working one on one or with small groups.

Perhaps the unfocused students need small group instruction in order for them to be less distracted, to achieve success in mathematics, and to access their metacognitive abilities. However, I do not see this as feasible with the current time constraints and curriculum demands faced by teachers. Students need to take on more responsibility for their own learning. Whether or not practice in planning, monitoring and evaluating will be able to control a personality trait such as hyperactivity or alter low self-esteem remains an unknown.

Question 2. Which children are aware of their own metacognition?

Metacognitive processing is an attribute that most of the children could access, but for various reasons some students could not do so effectively. Students who were focused on their studies and wanted to do well demonstrated through journal comments that they could focus on strategies and were aware of self-regulation. Children who were easily distracted, passive, or had low self-esteem appeared to accept that they could do little about their achievement.

Question 3. Does involvement in cooperative problem solving with a focus on metacognitive processing improve childrens' problem solving performance?

Small group work provides a support structure for students to interact and share their knowledge and ideas with a peer. For students to work well together there needs to be a sense of trust between the students. They must be able to make mistakes without ridicule.

An improvement in problem solving performance could not be credited solely to small group instruction. In September many of the students were not familiar with process problems, problem solving strategies, or a problem solving model. The level of frustration was high because of the challenge provided by the problems and poor computational skills. Attitudes toward problem solving became a focus. Students were encouraged to see problems as puzzles. Performance was evaluated according to the ability of the students to solve problems rather than how many problems they could solve. Speed in problem solving was de-emphasized and the enjoyment emphasized. Enjoyment came when the students began to have success. The teacher believed that an improvement in performance was due to an improvement in students' attitudes towards problem solving as well as instruction in problem solving processes and strategies.

Question 4. Is there a link between children's attitudes towards school learning and their awareness of their metacognitive processes?

This question is difficult to answer. Students who are bright and have a positive attitude to learning already have a sense that they can be successful and seem to demonstrate metacognitive processing more than students with a negative attitude towards school learning. Students who are weaker academically but achieve success through great effort on their part appear to have high levels of intrinsic motivation that enable them to focus on their learning. They know they can learn but that it takes them longer and requires more effort on their part. Children who lack interest in school or who have difficulty in concentrating on their school

work do not appear to access metacognitive processes for academic work.

Question 5. How can a teacher provide the type of social interaction between students and between student and teacher to facilitate the development of metacognition?

Again, this is a another difficult question to answer because the social dynamics within a classroom can be very challenging to manage. The fundamental management goal is to provide for the physical and psychological safety of all the children. The dynamics of the varying levels of social skills within a class sets the climate and modifies instructional strategies. The selection, teaching, and reinforcement of social skills is necessary for effective group work and class discussions.

More than social interaction must be provided. Explicit instructions on what the teacher expects of the students (e. g., assignment completion, work habits, goal setting, and journal writing) must be provided and consistently monitored. Children are generally eager to please their teacher, and when they see their teacher making a commitment, they will over time also make a commitment.

Perhaps the direct teaching of social skills (e. g. giving positive feedback, cooperating on a task, sharing leadership) may play a greater role in facilitating interaction between students and in facilitating mediated learning than is presently realized.

Question 6. Can theories on metacognition be integrated into existing teaching strategies?

The theories on reflective access, self-regulation, executive control, and other-regulation were reflected in the teaching strategies of journal writing, use of the Polyan model for problem solving, and establishing an interactive learning environment that focused on small group activities. Journal writing was an effective teaching strategy for making students think about what they were learning in mathematics class, what they understood, and what they could do to improve their mathematics performance. For the teacher, journal writing highlighted the differences among the students in their ability to demonstrate reflective access and self-regulation. The Polyan model that was used as a framework for problem solving provided experiences that allowed the students to see that tasks have a before, a during, and an after component, and that evaluating, planning, regulating, and revising take place at each stage. Small group activities as well as my interactions as a "mediator" and "model" with students facilitated other-regulation. Journal comments portrayed the influence that partners had on each other's learning. In these ways, theories on metacognition were integrated into existing teaching strategies.

In summary, it is the responsibility of teachers to actively involve students in their learning. If problem solving skills improve when there is dialogue between students, a teacher needs to search for techniques that will further enhance this teaching strategy. A focus on metacognitive processing which emphasizes decision making and thinking skills such as planning, monitoring, and evaluating has value even if it takes several years for the goals to

achieved. Students need to understand that they have the ability to make their own decisions. Through reflective access, self-regulation, other regulation, and executive control the students will be able to identify their personal strengths and weaknesses and focus effectively on being active learners.

References

Allan, S. D. (1991). Ability-grouping research reviews: What do they say about grouping and the gifted? Educational Leadership, 48(5), 60-65.

Anthony, B. & Hudgins, B. B. (1978). Problem-solving processes of fifth-grade arithmetic pupils. Journal of Educational Research, 72, 63-67.

Azzolino, A. (1990). Writing as a tool for teaching mathematics: The silent revolution. In T. J. Cooney & C. R. Hirsch (Eds.), Teaching and learning mathematics in the 1990s (pp.92-97). Reston, VA: National Council of Teachers of Mathematics.

Bauersfeld, H. (1988). Interaction, construction and knowledge: Alternative perspectives for mathematics instruction. In D. A. Grouws, T. J. Cooney, & D. Jones (Eds.), Effective mathematics teaching (pp. 27-46). Reston, VA: National Council of Teachers of Mathematics.

British Columbia Ministry of Education. (1987). Mathematics curriculum guide 1-8. British Columbia: Schools Department Curriculum Development Branch.

Brown, A. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert & R. H. Kluwe (Eds.), Metacognition, motivation, and understanding (pp. 65-116). Hillsdale, NJ: Lawrence Erlbaum.

Campione, J. C., Brown, A. L. & Connell, M.L. (1988). Metacognition: On the importance of understanding what you are doing. In R. I. Charles & E. A. Silver (Eds.), The teaching and assessing of mathematical problem solving (pp. 93-114). Reston, VA: National Council of Teachers of Mathematics.

Connelly, R., Marsh, F., Sarkissian, J., Calkins, T., Hope, J., O'Shea, T., Sharp, N., Taschuk, H., & Tossell, S. (1987). Journeys in math 6. Canada: Ginn Publishing Canada Inc.

Costa, A. L. (1984). Mediating the metacognitive. Educational Leadership, 42(3), 57-62.

Dreyfus, H. & Dreyfus, S. (1986). Mind over machine. New York: Free Press.

Dewey, J. (1902). The child and the curriculum. Chicago, Ill: University of Chicago Press.

Feuerstein, R. (1979). Instrumental enrichment. Baltimore, MD: University Park Press.

Flavell, J. H. (1976). Metacognitive aspects of problem-solving. In L. B. Resnick (Ed.), The nature of intelligence. Hillsdale, NJ: Erlbaum.

Garofalo, J. & Lester, F. K. (1985). Metacognition, cognitive monitoring, and mathematical performance. Journal for Research in Mathematics Education, 16, 163-176.

Garofalo, J. & Lester, F. K. (1987). The influence of affects, beliefs, and metacognition on problem-solving behaviour: some tentative speculations. Paper prepared for the annual meeting of the American Educational research Association, Washington, D. C. April, 1987.

Garner, R. (1988). Metacognition and reading comprehension. Norwood, NJ: Ablex.

Gavelek, J. R. & Raphael, T. E. (1985). Metacognition, instruction, and the role of questioning activities. In D. L. Forrest-Pressley, G. E. MacKinnon, & T. G. Waller (Eds.), Metacognition, cognition, and human performance: Instructional practices Vol. 2, (pp.103-132). Orlando, FL: Academic Press.

Graves, T. (1991). The controversy over group rewards in cooperative classrooms. Educational Leadership, 48(6), 77-79.

Hyde, A. & Bizar, M. (1989). Thinking in context: Teaching cognitive processes across the elementary school curriculum. White Plains, NY: Longman.

Johnson, D. W., Johnson, R., & Holubec, E. (1988). Cooperation in the classroom. Edina, MN: Interaction Book Company.

Johnson , D. & Johnson, R. T. (1989). Cooperative learning in mathematics education. In P. Trafton and A. Schultz (Eds). New Directions for Elementary School Mathematics (pp. 234-245). Reston, VA: National Council of Teachers of Mathematics.

Johnson, D. W. & Johnson, R. T. (1990). Social skills for successful group work. Educational Leadership, 47(3), 29-33.

Jones, B. F., Palinscar, A. S., Ogle, D. S., & Carr, E. G. (Eds.). (1988). Strategic teaching and learning: Cognitive instruction in the content areas. Alexandria, VA: Association for Supervision and Curriculum Development.

Kohn, A. (1991a). Group grade grubbing versus cooperative learning. Educational Leadership, 48(4), 83-87.

Kohn, A. (1991b). Don't spoil the promise of cooperative learning. Educational Leadership, 48(4), 93-94.

Lester, F. K. (1983). Trends and issues in mathematical problem solving research. In R. Lesh & M. Landau (Eds.) The acquisition of mathematical concepts and processes (pp.229-261). New York: Academic Press.

Lester, F. K. (1988). Reflections about mathematical problem-solving research. In R. I. Charles & E. A. Silver (Eds.), The teaching and assessing of mathematical problem solving (pp. 115 -124). Reston, VA: National Council of Teachers of Mathematics.

Marzano, R. J., & Arredondo, D. E. (1986). Restructuring schools through the teaching of thinking skills. Educational Leadership, 43(8), 20-26.

Marzano, R. J., Brandt, R. S., Hughes C. S., Presseisen, B.Z., Rankin, S. C., & Suhor, C. (1988). Dimensions of thinking: A framework for curriculum and instruction. Alexandria, VA: Association for Supervision and Curriculum Development.

Narode, N. (1989). Metacognition in math and science education. Abstract, ERIC Document Reproduction Service No. ED 291 558.

Peters, T., & Waterman, R. H. (1982). In search of excellence. New York: Harper and Row.

Peterson, P. L. & Swing, S. R. (1985). Students' cognitions as mediators of the effectiveness of small-group learning. Journal of Educational Psychology, 77(3), 299-312.

Polya, G. (1945). How To Solve It. Princeton, NJ: Princeton University Press.

Pressley, M., Borkowski, J., & O'Sullivan, J. (1985). Children's metamemory and the teaching of memory strategies. In D. L. Forrest-Pressley, G. E. MacKinnon, & T. G. Waller (Eds.), Metacognition, cognition, and human performance. Orlando, FL: Academic Press.

Pressley, M. & Harris, K. R. (1990). What we really know about strategy instruction. Educational Leadership, 48(2), 31-33.

Reid, J., Forrestal, P., & Cook, J. (1990). Small group learning in the classroom. Toronto: Heinemann/Irwin.

Ross, J. A. & Raphael, D. (1990). Communication and problem solving achievement in cooperative learning groups. Journal of Curriculum Studies, 22(2), 149-164.

Schewel, R. H. & Waddell, J. G. (1986). Metacognitive skills: Practical strategies. Academic Therapy, 22, 19-25.

Schoenfeld, A. H. (1985a). Metacognitive and epistemological issues in mathematical understanding. In E. Silver (Ed.), Teaching and learning mathematical problem solving: Multiple research perspectives (pp. 361-379). Hillsdale, NJ: Lawrence Erlbaum.

Schoenfeld, A. H. (1985b). Mathematical problem solving. New York: Academic Press.

Schoenfeld, A. H. (1987a). Cognitive science and mathematics education. Hillsdale, NJ: Lawrence Erlbaum.

Schoenfeld, A. H. (1987b). What's all the fuss about metacognition? In A. H. Schoenfeld (Ed.), Cognitive science and mathematics education. (pp. 188-216). Hillsdale, NJ: Lawrence Erlbaum.

Silver, E. A. (1985). Research on teaching mathematical problem solving: Some under represented themes and needed directions. In E. A. Silver (Ed.), Teaching and learning mathematical problem solving: Multiple research perspectives (pp. 247-266). Hillsdale, NJ: Lawrence Erlbaum.

Slavin, R. E. (1988). Cooperative learning and student achievement. Educational Leadership, 46(2), 31-33.

Slavin, R. E. (1991a). Synthesis of research on cooperative learning. Educational Leadership, 48(4), 71-82.

Slavin, R. E. (1991b). Group rewards make groupwork work. Educational Leadership, 48(4), 89-91.

Slife, B., Weiss, J., & Bell, T. (1985). Separability of metacognition and cognition: Problem-solving in learning disabled and regular students. Journal of Educational Psychology, 77(4), 437-445.

Szetela, W., Super, D., & Seidenberg, F. (1982). Houghton Mifflin mathematics 6 problem solving activities. Markham, Ont: Houghton Mifflin Canada Ltd.

Webb, N. M. (1982). Students' interaction and learning in small groups. Review of Educational Research, 20(3), 411-423.

Wertsch, J. V., McNamee, G. D., Mclane, J. B. & Budwig, N. A. (1980). The adult-child dyad as a problem solving device. Child Development, 51, 1215-1221.

Vygotsky, L. S. (1978). Interaction between learning and development. In M. Cole, V. John-Steiner, S. Scribner, & E. Sougerman (Eds.), Mind in society: The development of higher psychological processes (pp.79-91). Cambridge, MA: Harvard University Press.